Enhancement of the United States Naval Academy (USNA) Polar Science Program (PSP)

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LONG-TERM GOALS

The United States Naval Academy's Polar Science Program is introducing future Naval Officers to the Arctic environment through project based learning and field experiments. Introducing them to the

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challenges that the harsh polar environments pose, will help better prepare them for possibly operating there one day as Navy and Marine Corps Officers.

OBJECTIVES

The USNA PSP continues to spearhead undergraduate engineering and science projects to develop low cost, low power Arctic Observing Platforms. The culmination of the design, build, test and deployment process is a annual field experiment, the Naval Academy Ice Experiment (NAICEX), out of Barrow, AK.

APPROACH

The USNA academic curriculum culminates with a senior capstone or independent research course. USNA PSP has engaged the Aerospace Engineering, Ocean Engineering, Electrical Engineering, Computer Science, and Oceanography Departments to complete Arctic Observing Platform projects. SRI International has provided in kind support to mentor the students remotely and on site to develop unique platforms that provide near real time environmental data from the Arctic. These platforms included web cams, hydrophones, and metorological sensors that will report into the International Arctic Buoy Program network of Arctic drifters. The students also developed the power control systems, and are constantly improving on current designs, allowing for the integration of new sensors that are not currently common in the Arctic.

WORK COMPLETED

During it's first year of ONR Support, the USNA PSP designed, built and deployed three sensors to the Polar Regions. Five Midshipmen and two faculty members from USNA participated in the first USNA coordinated field experiment NAICEX13 in Barrow, AK. Development of future sensor packages continues to move forward, with smaller, lower power, and more cost effective measures then current industry standards.

1) USNA PSP deployed three sensors in FY13 (Fig.1). The Arctic Observing Platforms are nicknamed 'IceKids or IK' after the USNA mascot, Bill the Goat. IceKid1 was a simple web cam system designed for deployment to Antarctica for near real time observations of a Dartmouth snow chemistry tower. IK1 was then repositioned on Pine Island Glacier in support of the NPS under ice shelf profiling site. IceKid2A (acoustic) integrated a hydrophone into the system for near real time underwater acoustic monitoring. IceKid3T (temperature) used a high precision all in one Vaisala weather sensor and deployed on land at the University of Washington's Arctic Obsrving Experiment (AOX) site.

2) USNA PSP successfully coordinated and executed the first Naval Academy Ice Experiment (NAICEX) in March 2013 out of Barrow, AK. This experiment included setting up survey lines on the fast ice just offshore, and conducting sea ice and snow measurements. These observations were coordinated with NRL and NASA over-flights to help provide better understanding towards the accuracy of the airborne sensors. Collaborations included the University of Washington, University of Delaware, NRL, CRREL, and NSF. Nine students (5 undergraduate and 4 graduate) participated along with ten other researchers during ten days of field work on the shore fast ice off Barrow (Fig. 2). The measurements obtained will provide datasets for future years of midshipman research projects.

3) Midshipmen engineering and science projects continue to develop with the addition of five Electrical Engineering students for the next academic year. This past year, we had two Aerospace Engineers, three Ocean Engineers, and three Oceanography students all involved in USNA PSP projects. These projects included the design, build, test and deployment of three Arctic Observing Platforms. Also a submarine deployable, arctic capable, buoy hull design was designed, modeled, and tested. And initial analysis was performed on the NAICEX snow and ice data by midshipmen.

RESULTS

The engineering challenges of developing a Arctic Observing Platform that can survive the harsh conditions, were fully realized by the midshipmen. Troubleshooting in the field was ineffective, and several design modifications were noted for future builds (Fig. 3). Data was successfully collected from all platforms, however, hardware issues degraded IK1 and IK2A. IK3T is still collecting important weather data, while monitoring the AOX site to help better understand how the IABP buoys are performing (Fig. 4). The near real time webcam information has proved extremely beneficial for both visual observations, and logistical planning, and was used extensively to help coordinate flight operations while visiting the Dartmouth site in Antarctica.

The acoustic sensing IceKid2A was a significant accomplishment, in that it provided near real time acoustic data from a remote platform. Prior to deployment in March of 2013, the acoustic capability of IK2A successfully exercised in two scenarios. In the first scenario, the hydrophone was deployed at the Naval Academy pier and data was collected locally. In the second, data was transmitted via iridium modem hourly. The goal of the first test was to test automation and identify spectral signatures associated with acoustic noise cycles (shipping, precipitation, rain) over a four day period. One minute of data was collected each quarter hour and spectral noise averages were computed within each 33 1/3 octave band. Noise levels were retained in memory and downloaded at the termination of the event. Spectral averages were layered to reveal diurnal variations in the noise field. The sensor proved reliable as a broadband rain, wind and shipping traffic noise gauge. The results are displayed in figure 5.

IK2A's first field test was in Barrow Alaska in March of 2013. Unfortunately, power board issues restricted full automation and only two datasets were collected. Reduced from a quarter hour to hourly sampling, the first dataset consists of 30 spectral signatures collected when the hydrophone was exposed to the air. The second dataset consists of 5 spectral signatures collected when the hydrophone was deployed under ice in approximately 30 feet of water. The results are displayed in figure 6.

The 60 Hz noise fundamental and 120 Hz harmonic (bins 9 and 12 of the spectral signature) are clear indicators of a 60 Hz power noise ground. For the "outside building" data, it is suspected that the hydrophone cabling (severed to construct a watertight seal in the cooler wall thus compromising the cable shielding) acted as an antenna for surrounding EM noise. In the case of the "under ice" event, the author suggests that a ground, caused by the power generation plant displayed in figure 4, may exist in the water column as well. In order to address these challenges, the next design will include band pass filtering and elimination of the watertight connection.

IMPACT/APPLICATIONS

USNA PSP is developing sensor packages that have yet to be proven effective and low cost from industry. The engineering freedom of the undergraduate capstone course, allows for alternative energy sources, communications packages, and sensor suites to be explored. Also the collaborations established with other institutions allows for a very cost effective, robust, field experiment to occur regularly out of Barrow, AK. NAICEX is a ideal instrument deployment opportunity for other interested investigators, and the plans for 2014 are to move out to indivdual drifting ice floes for both instrument deployments and measurements.

The IceKid observing platforms have proven to be a useful tool for real-time monitoring of field experiments. Their small size and packaging allow them to easily accompany researchers into the field. As an example, the Dartmouth science team needed to periodically visit their field site, via helicopter, to collect samples when the snow socks on their tower filled up. In the past, these visits were done blindly, but with IceKid1 sending back real-time images of the site, the team could optimize their flight operations to only visit when samples were ready and the weather was good.

IceKid2A, along with the hydrophone and accompanying on-board data processing, allow for monitoring of the ambient background noise with the results transmitted in real-time for remote observation. One potential future application for this system is to aid in the bowhead whale count near Barrow.

IceKid3T, has an ultrasonic anemometer in addition to the basic meteorological sensors. Understanding the effectiveness of this sensor in comparison to the autonoumous mechanical anemometers, and full attended aneometers at the AOX test site will improve our ability to measure wind from the open water, through the marginal ice zone and into the pack ice.

Future directions for the systems include reducing power usage and application of various energy harvesting techniques to allow them to operate year-around in the polar environment.

RELATED PROJECTS

NAICEX participants included the University of Washington's Polar Science Center, the University of Delaware's Geography Department, the Naval Research Laboratory, and United States Army Cold Regions Research and Engineering Laboratory. The teams worked together collecting snow and ice data for comparison to airborne sensors (http://www.usna.edu/PSP/NAICEX_s13/index.php).

The USNA PSP Arctic Observing Platforms are also integrated into the International Arctic Buoy Program array of Arctic Drifters (http://iabp.apl.washington.edu/).

PUBLICATIONS

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FIGURES

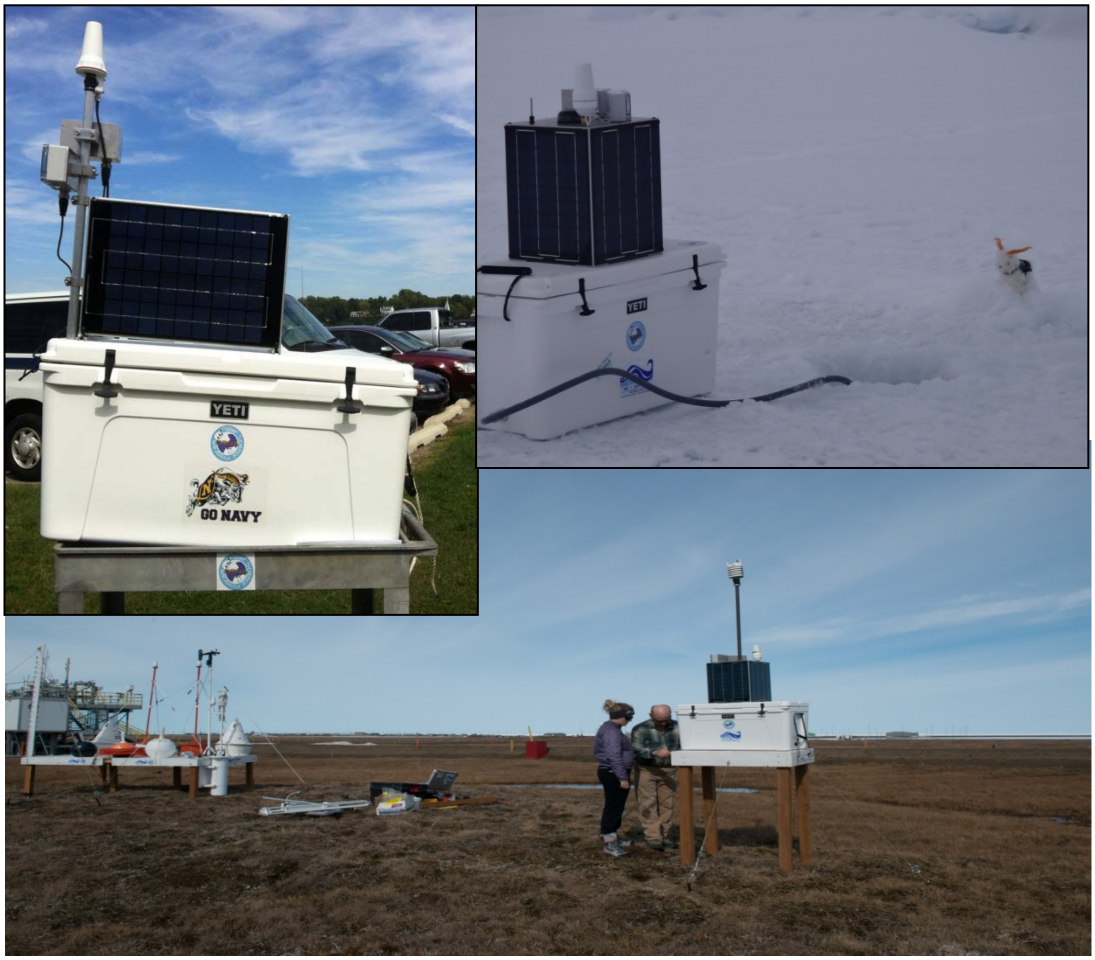

Figure1: (top left) IK1 undergoing testing at USNA; (top right) IK2A with hydrophone through the sea ice offshore Barrow, AK.; (bottom) IK3T at AOX site in Barrow, AK. The AOX site is monitoring temperature biases between all buoy systems currently operated by the International Arctic Buoy Program (IABP). Mishipman Julia Zook works with University of Washington Engineer Jim Johnson on the IK3T during her summer internship to Barrow, AK.

Figure 2: The NAICEX field site just offshore Barrow, AK on the shore fast ice. USNA Midshipman drilling holes through the sea ice for thickness measurements. Over 40 holes were drilled along a 3 km survey line to better understand the under ice topography.

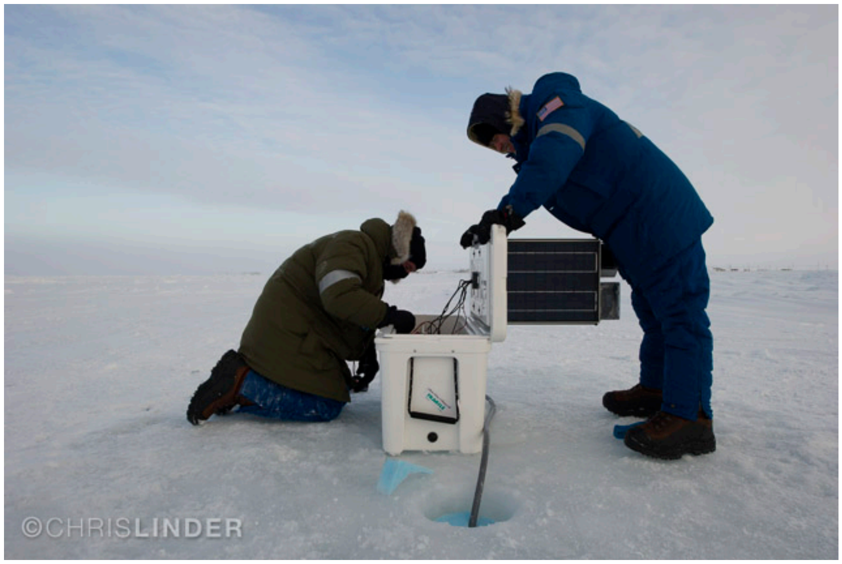

Figure 3: Two aerospace engineering students from the U.S. Naval Academy attempt to troubleshoot the Arctic Observing Platform IceKid2A while on the ice off Barrow, AK. The design and build of this platform was the midshipmens senior capstone design project. IK2A pis solar powered, and capable of relaying under ice acoustic data in near real time via satellite communications.

Figure 4: Near real time webcam image from IK3T at the AOX site in Barrow, AK. 10 different Arctic drifters and other temperature sensors are co-located to determine if there is any bias between instruments. The IK3T has a meteorological package as well as webcams that will identify any snow accumulation or freezing up of instruments.

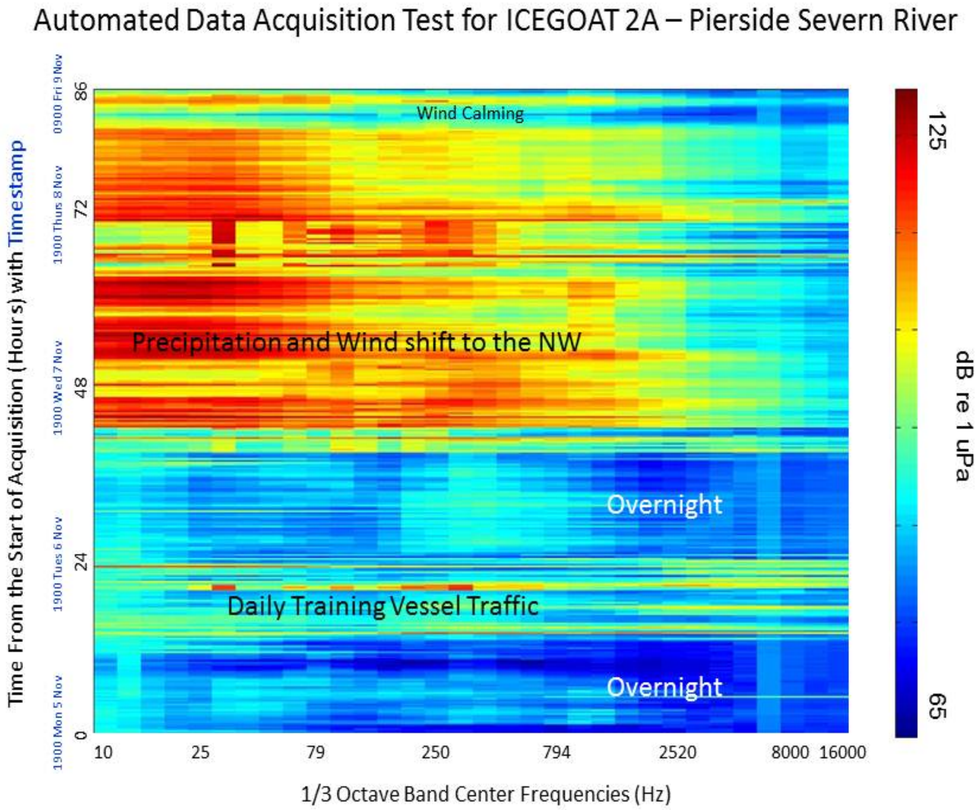

Figure 5: Pier side 1/3 octave spectral noise levels (dB re 1uPa) for the Severn River automated test. Data was stored locally and post processed for visualization.

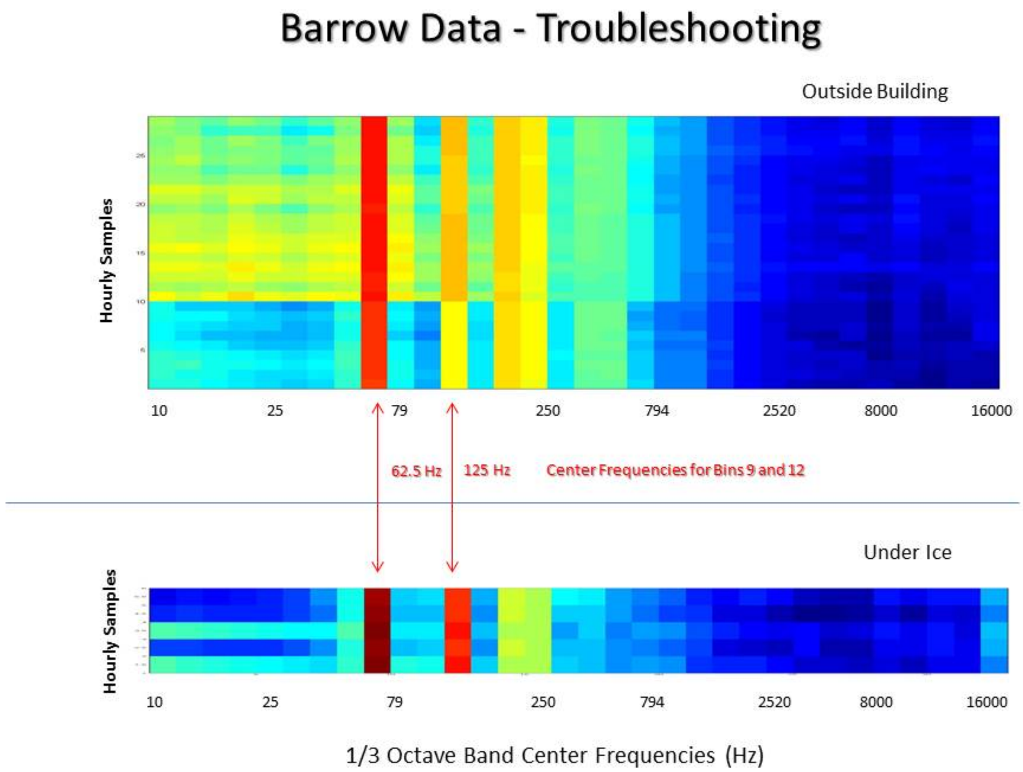

Figure 6: Open air (top panel) and under ice (bottom panel) spectral signatures. Relative 1/3 octave noise levels are shown for the 30 hours of open air and 5 hours of under-ice sampling. Single spectral signatures were transmitted hourly via iridium modem. Data was downloaded from the sensor's internet site and post processed for visualization. A 60 Hz noise ground and its 120 Hz harmonic are clearly visible.